

A *Swift* BAT Look at Super-Orbital X-ray Binaries

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Abstract. We present the results of a study with the *Swift* Burst Alert Telescope in the 14 – 195 keV range of the long-term variability of 5 low mass X-ray binaries with reported or suspected super-orbital periods — 4U 1636-536, 4U 1820-303, 4U 1916-053, Cyg X-2 and Sco X-1. No significant periodic modulation was detected around the previously reported values in the 4U 1916-053, Cyg X-2 or Sco X-1 light curves. The ~ 170 d period of 4U 1820-303 was detected up to 24 keV, consistent with the proposed triple system model. The ~ 46 d period in 4U 1636-536 was detected up to 100 keV, clearly inconsistent with variable photoelectric absorption via a warped precessing disc. We speculate that the appearance of this modulation after 4U 1636-536 entered the low/hard state indicates that this variability could be linked to jet precession such as observed in SS 433.

1. Introduction

Long-term “super-orbital” periodic variability has been observed in soft X-rays from over 30 X-ray binaries with the All Sky Monitor (ASM) on the *RXTE* satellite (e.g. Sood et al. 2007). Also known as ‘long’ or ‘third’ periods, these modulations are defined simply as any periodic variability greater than the orbital period. The precession of a warped accretion disc modulating the X-ray flux from the compact object is currently the favoured model (e.g. Wijers & Pringle 1999). Ogilvie & Dubus (2001) showed that while radiation driven warping gives a coherent picture of super-orbital periods in some systems, this model cannot explain the observed phenomena in all cases.

The limited spectral coverage of the *RXTE* ASM has so far precluded long-term studies of super-orbital variability at high energies. The launch of *Swift* in 2004 saw the arrival of a wide field monitoring instrument capable of complementing the *RXTE* ASM in hard X-rays – the Burst Alert Telescope (BAT; Barthelmy et al. 2005). In this paper we present the results of a search for the previously reported super-orbital modulation of 5 low mass X-ray binaries in the BAT 14 – 195 keV light curves.

2. Data Analysis

The BAT 14 – 24 keV (A), 24 – 50 keV (B), 50 – 100 keV (C) and 100 – 195 keV (D) light curves were used for these analyses, after correction for the off-axis position and earth

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occultations. For comparison, the *RXTE* ASM 1.5 – 12 keV 1 d average light curves for the same time span were analysed to cover the low energy range of the spectrum.

The modified weighting scheme developed by Corbet, Markwardt & Tueller (2007) was used. In this method, individual data points are given weights based on both the non-uniform measurement uncertainties and the intrinsic source variability. Power spectra were generated for each of the weighted light curves using the fast periodogram FASPER subroutine of the Lomb-Scargle periodogram (see Press & Rybicki 1989, and references therein), with the 99% white noise significance levels estimated using Monte Carlo simulations (e.g. Kong, Charles & Kuulkers 1998).

3. Results and Discussion

No evidence for the reported super-orbital periods in 4U 1916-053 (199 d; Grindlay 1992), Cyg X-2 (77 d; Smale & Lochner 1992) or Sco X-1 (37 d/62 d; Peele & White 1996; Ogilvie & Dubus 2001) was found in the ASM or any of the BAT light curves. The power spectra were instead dominated by significant low-frequency noise, with no peaks appearing to indicate the presence of real long-term periodic modulation. The super-orbital periods in 4U 1916-053 and Cyg X-2 were originally detected using *Vela 5B* data, while the detection of super-orbital modulation in Sco X-1 was made using only the first 9 months of ASM data. It is thus apparent that either the reported detections were spurious or the mechanisms behind the super-orbital variability in each of these three systems has since ceased. In comparison, the ~ 46 d and ~ 170 d variability previously reported for 4U 1636-536 (Shih et al. 2005) and 4U 1820-303 (Priedhorsky & Terrell 1984) respectively were detected in both the ASM and BAT light curves (Figure 1).

The ~ 170 d period in 4U 1820-303 has been attributed to variable accretion linked to the presence of a third body in this system, whereby the eccentricity of the inner orbit is modulated by tidal effects produced by the outer body (Chou & Grindlay 2001). Transitions between the high/soft and low/hard states over this timescale are linked to variability in the accretion rate (Bloser et al. 2000) and the movement in and out of the inner region of the accretion disc (see for example Malzac 2007), thus modulating the thermal Comptonisation region of the spectrum. This thermal Comptonisation component has been seen to dominate the spectrum up to ~ 50 keV, above which a high energy non-thermal tail is dominant (Tarana et al. 2007). The non-detection of the modulation above 24 keV is therefore due to a lack of sensitivity of the BAT (as the modulation should be present in the 24 – 50 keV band), precluding us from testing the idea that the modulation also affects the non-thermal tail and thus extends to higher energies.

The detection of the ~ 46 d period in 4U 1636-536 up to 100 keV is clearly inconsistent with variable photoelectric absorption by a warped precessing disc, as absorption should effect only the low energy (ASM) data. Fiocchi et al. (2006) linked the recent reduction in X-ray flux and the appearance of a high energy tail detected by *INTEGRAL* in the spectrum of 4U 1636-536 to the onset of jet formation. The detection of the modulation at energies where the high energy tail is dominant (i.e. > 30 keV) indicates that both the thermal Comptonisation and high energy tail components are varying over this timescale. Coincidentally, the ~ 46 d modulation first appears in the ASM data around the same time as this transition to the low/hard state. The appearance of a high energy power law tail in the spectrum in conjunction with the first detection of the ~ 46 d period and the reduction in flux is intriguing, implying a link between the three phenomena. If the assertion made by Fiocchi et al. (2006) is correct — that the high energy tail is produced in compact jets — then the ~ 46 d modulation is likely also associated in some way with the jets. The modula-

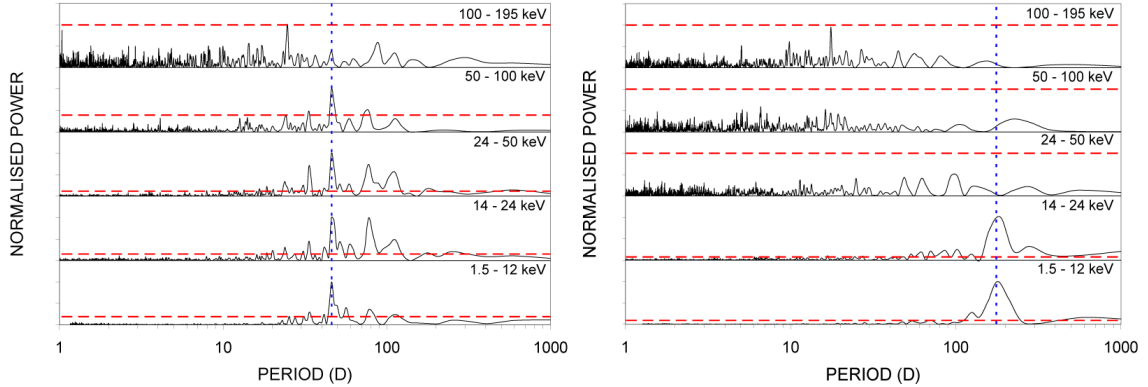


Figure 1. Normalised power spectra of the ASM and BAT light curves of 4U 1636-536 (left panel) and 4U 1820-303 (right panel). The red horizontal dashed lines indicate the 99% white noise significance levels. The blue vertical dotted line indicates the location of the reported super-orbital periods at ~ 46 d (4U 1636-536) and ~ 170 d (4U 1820-303) respectively.

tion could thus be tied to either transient jet formation or the precession of the jets (linked in turn to the precession of a warped disc) in a similar fashion as seen in SS 433 (Margon 1984). Further observations at radio wavelengths are being sought in order to confirm this hypothesis.

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